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Hydraulic Mulch Application Rates for Control of Soil Erosion

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ıydraulic Mulch Application Rates for Control of Soil Erosion

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Abstract:	Three commercial mulches, Conwed, Verdyol and Fibramulch, were compared at five rates of application to determine their effect on turf establishment. The mulch application rates were varied from 1000 to 2200 kg/ha while the amounts of seed and fertilizer were held constant. Measurements of dry matter production and vegetative cover were made at three times over a five month period following the hydroseeding operation. On the first sampling dates, straw was clearly superior to the commercial mulches with respect to both horizontal vegetative cover and dry matter production. By the final sampling dates, the results obtained with the mulches and straw were all approximately the same. The early samplings for dry matter production and vegetative cover were considered the most relevant in the assessment of turf establishment. Measurements of horizontal vegetative cover also provide a more reliable indication of soil erosion control than does dry matter production. Vegetative cover and dry matter production generally increased as the rate of the mulch application increased. The relationship of the application rates to dry matter and vegetative cover were more consistent at rates greater than 1600 kg/ha. It is suggested that the Ministry's current rate of 1600 kg/ha is a reasonable minimum application rate for the commercial mulches tested.
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Key words:	application rates, Conweb, Fibramulch, hydraulic mulches, hydroseeding, mulching, red fescue, slope stabilization, straw, turf establishment, vegetative cover, Verdyol
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A. INTRODUCTION

Over the past decade, a number of new mulch materials have been marketed for use in hydroseeding operations. As a result of this increased variety the Ministry of Transportation identified a need to develop a standardized procedure for testing the effectiveness of new mulches and preparing guidelines for the standardization of the testing of them.

This study was designed to determine the optimum application rates for three different mulches; Conwed, Verdyol, and Fibramulch. The optimum application rates were considered as the rates at which turf cover was provided equivalent to a straw mulch. Consequently, a straw mulch application was used as a control plot in this study. The second function of this study was to develop a standardized procedure to test and evaluate new hydraulic mulches presented to the Ministry for consideration.

In essence, this study measured the effectiveness of three different mulches, applied at five different application rates, to produce turf equivalent to that of a straw mulch. Percentage vegetative cover and dry matter production were used as indicators of the effectiveness of each mulch and associated application rate. Standard Ministry fertilizer and seed rates were mixed with twice the standard water rate and used in the application of varying amounts of mulch to each experimental plot.

Section B of this report outlines the procedures used in this study to compare the effectiveness of each mulch and application rate from site preparation to sampling parameters. Section C provides a summary of observations with respect to erosion, vegetative cover analysis and dry matter production. Section D is a discussion of the results of the study including experimental design while Section E provides a summary and recommendations for additional study.

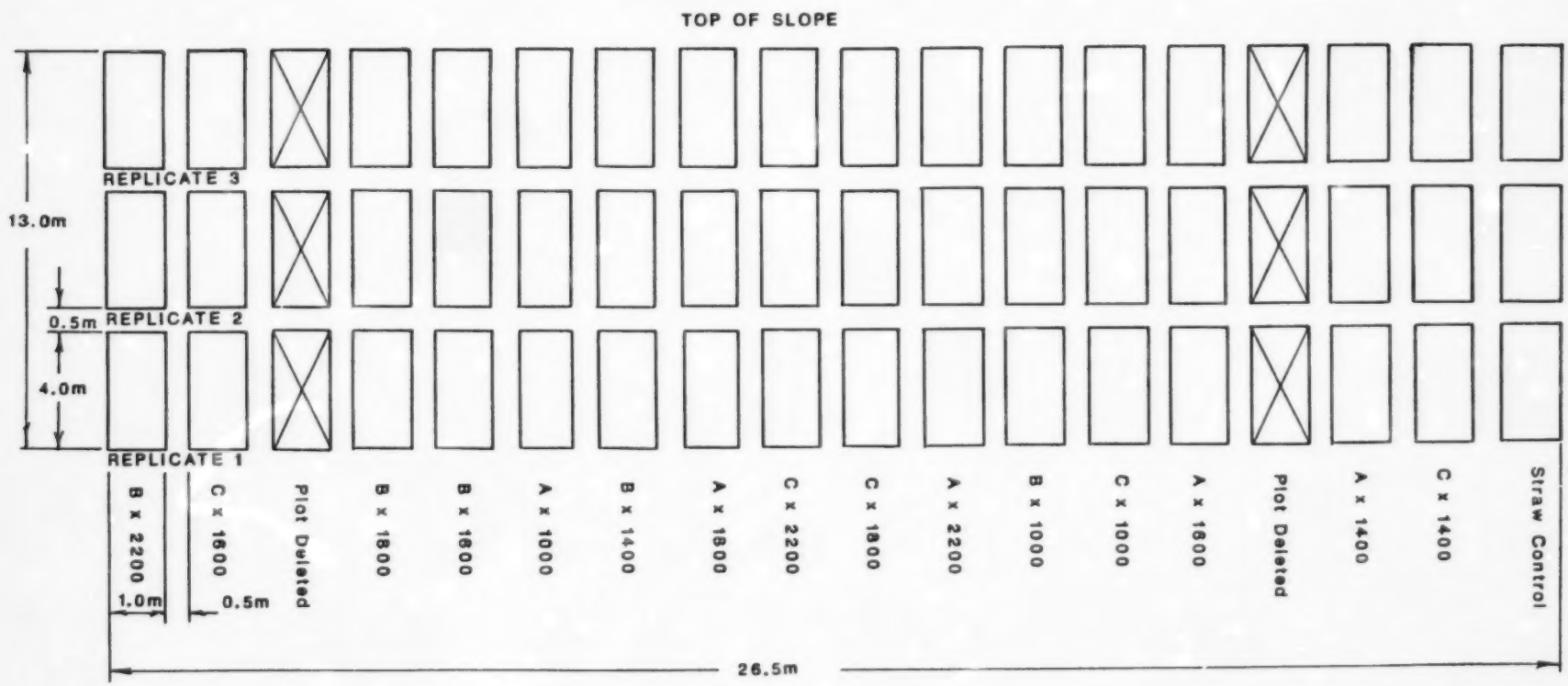
B. PROCEDURES

B.1. Experimental Design

The experimental site was laid out in a restricted, randomized complete block design where the three replicates represented three positions on the slope (Figure 1). Uniform applications of the mulch could be best achieved where the spraying was conducted over as large an area as possible. As a result, a restriction of having the same randomization used for each replication was employed to allow each treatment to be applied as a unit on the slope. To account for this restricted randomization the minimum probability level for statistical significance was decreased from the traditional P=0.05 level to 0.025.

FIGURE 1

FIELD PLOT PLAN



LEGEND

FORMAT

Bx2200

- Verdyol at 2200 kg./ha.

A	Conwed
B	Verdyol
C	Fibramulch

Plot size = 1.0m x 4.0 m

N.T.S.

The treatments were arranged as a 3 x 5 factorial consisting of three mulches; Conwed, Verdyol, and Fibramulch; and the proposed five rates of application; 1000, 1400, 1600, 1800, and 2200 kg/ha. A straw mulch control plot was used for a comparison of turf establishment.

Analysis of variance and multiple comparisons were carried out on all data. Linear and non-linear regression analyses were performed on percent vegetative cover and dry matter production data to determine their relationship with the mulch rate.

B.2. Site Preparation

The field site was located at the TCG Materials Limited gravel pit at Aberfoyle, Ontario, just north of Hwy. 401 and west of Brock Rd. The site within the gravel pit was located on a 3:1 south facing slope that had been recently graded. The subsoil is a gravelly, coarse sand with many fist-sized and larger, boulders. The native Dunfries sandy loam (gravelly phase) topsoil was spread over the subsoil with a small bulldozer to a depth of 15 cm (Photo 1).

Following topsoil application, the site was covered with a plastic sheet and a gaseous soil fumigant, methylbromide ('Dowfume'), was used to kill weed seeds in the topsoil (Photo 2). Individual plots measuring four meters long and one meter wide were staked out and separated by 0.5 m sod buffer strips (Figure 1). A total of sixteen treatment blocks, including the straw control, were used to apply each mulch at five different application rates. Each treatment block

Photo 1: Topsoil placement and levelling of slope.

Photo 2: Fumigation of the soil with methylbromide.

was separated into three replicate plots for each application rate and mulch type which resulted in 48 plots. Each plot was subdivided into sixteen quadrats, measuring 0.5 x 0.5 m. These quadrats were used for subsampling.

Because of errors in the application of the mulches on two of the replicate blocks, one set of replicate blocks was added at each end of the fumigated experimental site. These two end sets of plots were not fumigated.

B.3. Application Procedure

Once the site had been prepared and all plots staked, the mulches were applied. Application of the mulches began June 15 and was completed on June 18. A small portable (1135 litre) hydroseeder was used to mix and apply the three mulches (Conwed, Verdyol, and Fibramulch).

Normally, application rates specified by the Ministry (Table 1) for contractors are uniformly applied by varying the speed of the hydroseeding vehicle as it passes the area to be hydroseeded to achieve the desired rate. Nozzle flow rate is assumed to be constant. This procedure was not followed since there was insufficient room for a vehicle to achieve a constant speed driving past the plots and to avoid contamination of adjacent plots. Instead, the hydroseeder was placed at the top of the slope to allow for access to all plots.

Each mulch application, except the straw control, was applied in the following steps. The straw mulch was applied to a depth of between 25 and 50 mm, or approximately 4 tonnes per hectare. The straw application was conducted by a hydroseeding contractor after the seed, fertilizer and water were applied using the same procedure as outlined below.

1. One tank (1100 L) was mixed with the appropriate amounts of the constituents (seed, fertilizer, mulch) based on the standard Ministry specifications for each mulch. Water was added at twice the standard rate to dilute the mulch for ease of application.

2. The nozzle of the hydroseeder was adjusted to achieve the optimum spray width for the treatment block (approximately 1 m wide).

3. The nozzle was then calibrated to determine its flow rate in litres per second by weighing five 15-second flows from the nozzle and averaging the results.

4. The concentration of hydroseed mix for the 2200 kg/ha rate was determined and then correlated with the nozzle flow rate to determine the amount of time required to spray the three replicate plots. By varying the amount of the time each plot was sprayed, the desirable application rates of mulch could be achieved. To ensure equal amounts of fertilizer and seed were applied, seed and fertilizer was added to the mix to compensate for the shorter time of application involved in applying at lower rates of mulch.

5. The three replicates were sprayed by walking up and down the grass buffer between the plots. Spraying stopped when the previously calculated time requirement was reached. Only minor differences in the application of the mulch along the slope would have resulted from the completion of spraying during a pass since many total passes were conducted.

6. The volume left in the tank was determined. Based on a ratio of time required to apply the mulch at 2200 kg/ha versus 1800 kg/ha, seed and fertilizer was added to the remaining volume to ensure that each plot had the same amount of seed and fertilizer regardless of the mulch application rate.

7. Steps 5 and 6 were repeated until the 1000 kg/ha application was completed; the next mulch used repeated steps one through seven.

An error in the application of Fibramulch resulted in the actual application rates of 1237, 1735, 1800, 1940, and 2165 kg/ha instead of 1000, 1400, 1600, 1800, and 2200 kg/ha. The corrected values were used in the regression analyses. Photo 3 illustrates the site following the completion of the mulch application.

TABLE 1: MINISTRY OF TRANSPORTATION STANDARD MIXES AND RATES

MULCH		PRIMARY SEED		FERTILIZER		WATER
Type	Rate(kg) /10000 m^2	Type	Rate(kg) /10000 m^2	Type	Rate(kg) /10000 m^2	(L) /10000 m^2
Straw	25 to 50 mm deep with 1100L emulsified asphalt	Min.	100	8-32-16	350	7600
Conwed	1600	Min.	100	8-32-16	350	36540
Verdyol	1600	Min.	100	8-32-16	350	42220
Fibra-mulch	1600	Min.	100	8-32-16	350	34160

Min. - Ministry Seed Mix

Photo 3: Site following hydroseeding operation.

Photo 4: Analysis of ground cover.

B.4. Sampling Procedures

B.4.a. Vegetative Cover Analysis

The extent of horizontal vegetative coverage for each mulch was assessed by sampling four quadrats within each plot. These analyses were conducted three times during the study; on July 10, August 10, and September 23, 1987.

An acetate sheet measuring 0.5 x 0.5 m and having a grid delineating squares, each 0.02 x 0.02 m, was placed over a quadrat. Ten rows within the grid, consisting of 250 squares or 0.1 m^2, were randomly selected and the number of squares in which no vegetation was evident was counted (Photo 4). The resultant values, which were summed over the four quadrats, were used to calculate the percent vegetative cover on the plot.

B.4.b. Dry Matter Production

Destructive sampling of the grass was carried out on September 8 -11, September 30 -October 2, and October 26, 28, and 30, 1987 to determine dry matter production. The grass from within three quadrats on each plot was cut to within 1 cm of the soil surface with pruning shears, and bagged. Samples were dried at 80^{o} C for at least 48 hours, and their dry weights determined. Different quadrats, selected at random, were used at each sampling date. The dry matter values were summed over the quadrats to determine a total for the area measured in a plot. Dry matter data are expressed on a

weight per unit ground area basis. On the straw mulch control plot, the straw was raked away by hand to allow cutting of the grass at ground level.

C. RESULTS

Data measured for each replicate, treatment and replicate means, the analysis of variance and multiple comparisons are provided in Appendix A. A table of the regression parameters are provided in Appendix B.

C.1. Vegetative Cover Analysis

The measurement of vegetative cover was used to evaluate the mulches on their relative effectiveness in the prevention of erosion. The horizontal coverage on the soil surface would reduce the kinetic energy of the raindrops at the soil surface and prevent the dislodgement and transport of soil downslope. Since the ground surface is initially covered only by the mulch following the hydroseeding, both the ability of the mulch to resist raindrop impact and the ability of turf to establish for long term resistance under the mulch, are considered important. The establishment of an early cover of grass was considered to be of major importance in the prevention of erosion, and as such, vegetative cover on July 10 was used as a determinant of the early turf establishment.

Regression analyses revealed that vegetative cover on July 10 increased with increasing rates of mulch application and was greatest at a rate of 2200 for all mulches (Figure 2). This pattern remained constant over the subsequent dates of August 10 and September 23 (Figures 3 to 7). Figures 3 to 7 depict the change in the vegetative cover over the three sampling dates at each standard application rate. The values plotted for the Fibramulch were recalculated from the original data set using linear regression analysis so that direct comparisons can be made among the mulch types.

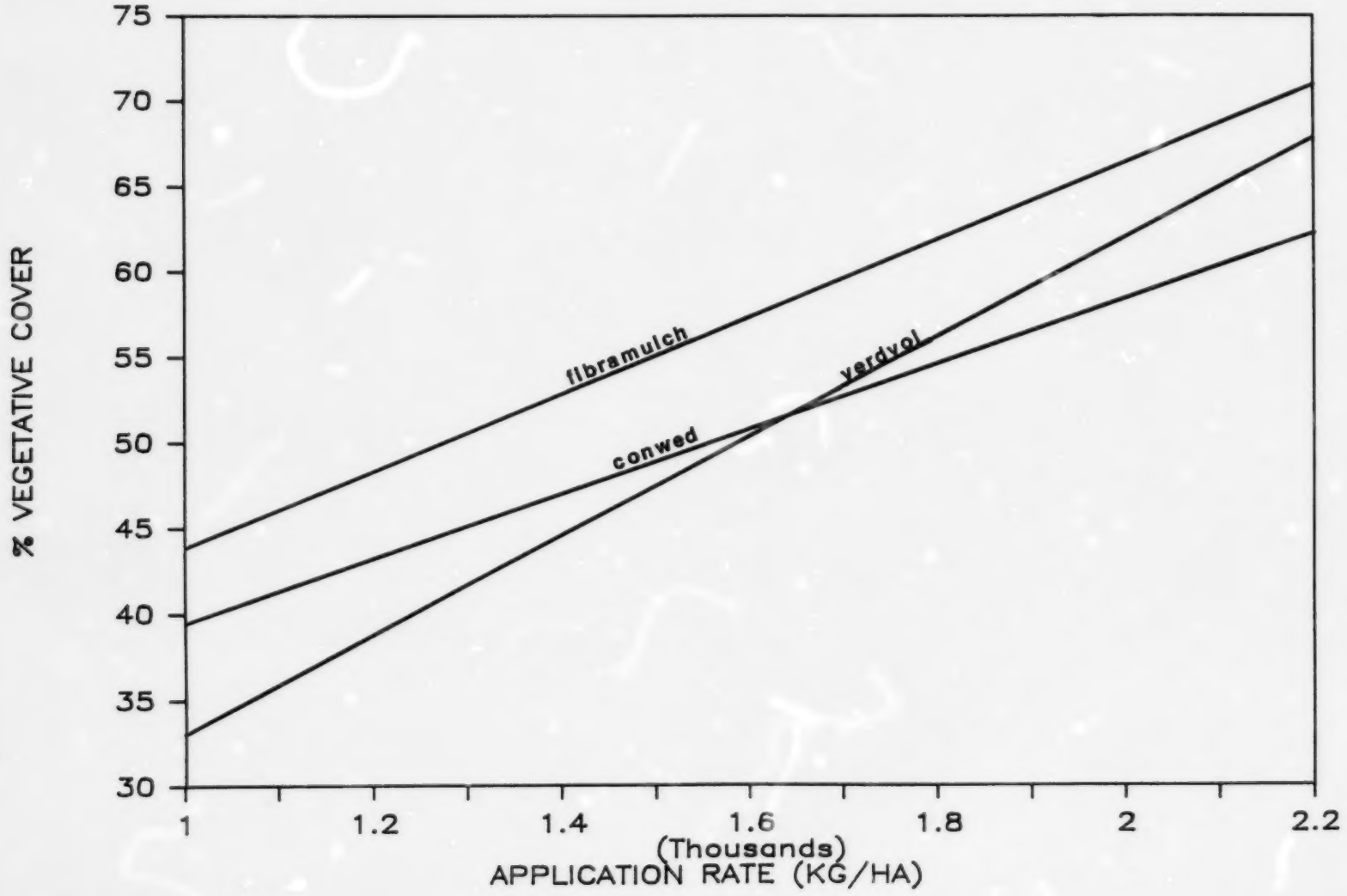
In general, averaged over all rates, Fibramulch provided more ground area coverage (61 and 70% on July 10 and August 10, respectively) than Conwed and Verdyol which both provided similar coverage (51 and 54% on July 10 and August 10).

More bare ground was apparent at the top of the slope where approximately half of the ground surface was covered by grass, compared with a sixty percent coverage at the bottom of the slope, on July 10. Similarly, on August 10, the grass accounted for 53% of the surface coverage of the ground at the top of the slope, and increased to 65% at the bottom. By September 23 vegetative cover averaged the same at all slope positions.

Since the growth of the grass in late summer was substantial, the vegetative coverage averaged 82% for the three mulches on September 23. Vegetative coverage under the mulches was not statistically different from the 90% vegetative cover achieved with the straw mulch.

FIGURE #2

LINEAR REGRESSION LINES OF PERCENT VEGETATIVE COVER VERSUS MULCH APPLICATION RATE (JULY 10)



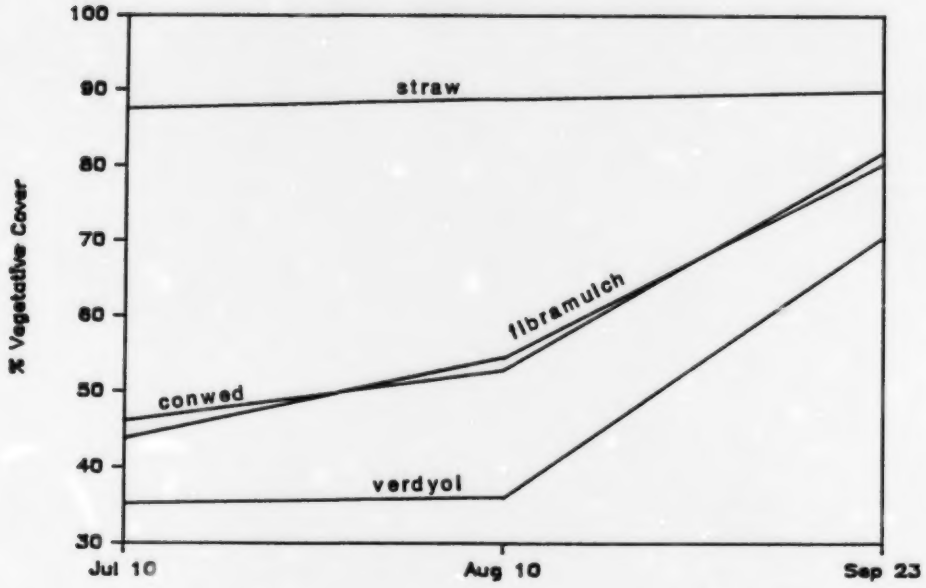


Figure 3: Percent vegetative cover versus time for a 1000 kg/ha mulch application.

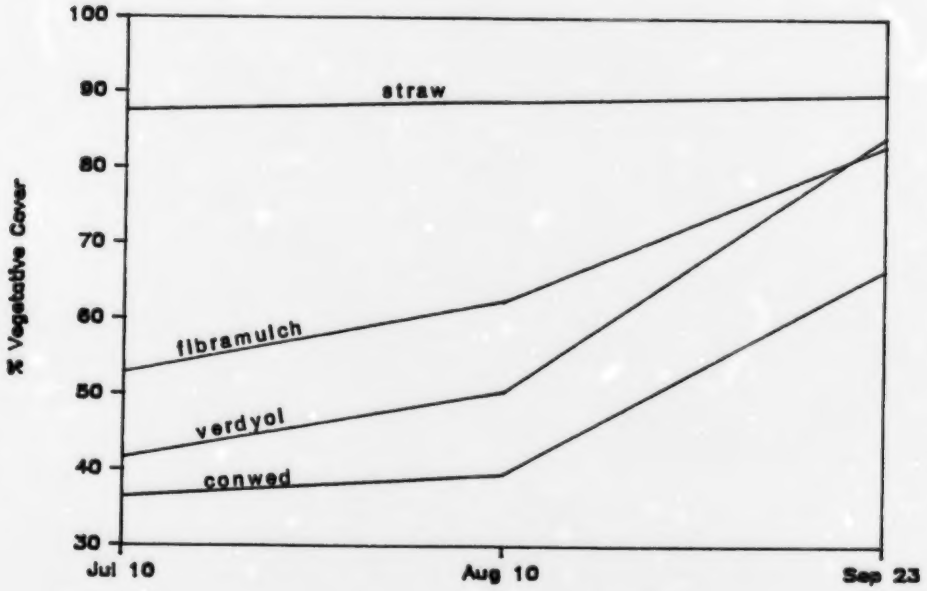


Figure 4: Percent vegetative cover versus time for a 1400 kg/ha mulch application

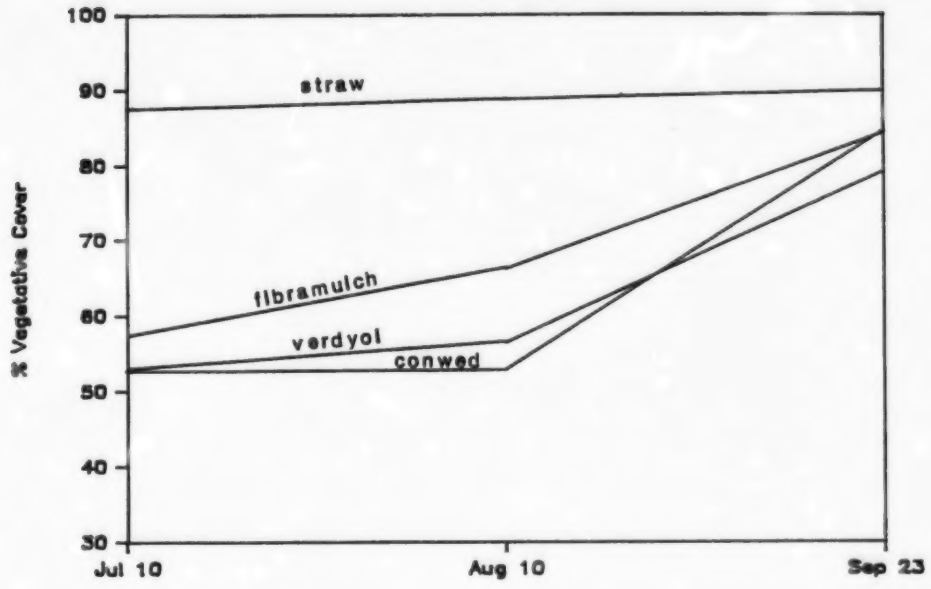


Figure 5: Percent vegetative cover versus time for a 1600 kg/ha mulch application.

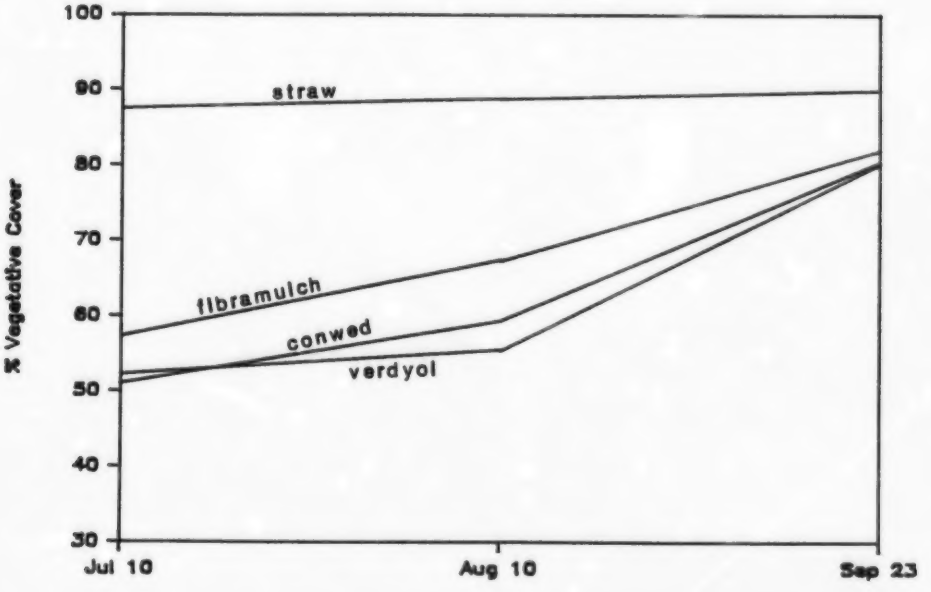


Figure 6: Percent vegetative cover versus time for a 1800 kg/ha mulch application.

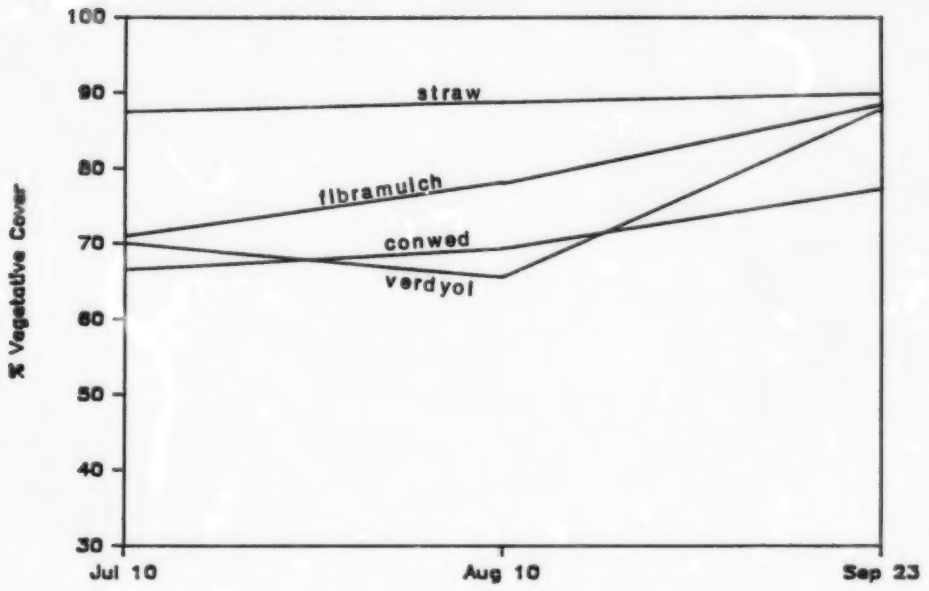


Figure 7: Percent vegetative cover versus time for a 2200 kg/ha mulch application.

The percent vegetative cover was greatest under the straw mulch for July 10 and August 10. Grass under the straw covered 88% of the ground area and did not change appreciably over the sample period from July to August.

C.2. Dry Matter Production

Dry matter yield is a measure of both the horizontal and vertical distribution of the vegetation. The horizontal component is the erosion effective component whereas the vertical component is the aesthetic effective component and the indicator of plant biomass production.

Dry matter production was insufficient for sampling until September 8.

By the September 30 sampling date, dry matter production had doubled from the September 8 sampling date and in most cases exceeded the levels recorded for the control, ie. straw. There was an approximate fifty percent increase in dry matter production from the late September sampling to the October sampling. At this time, the average dry matter production for the commercial mulches was similar to the straw mulch. The September 8 results for dry matter production were considered to be the most reflective of differences in mulches and application rates.

Results of the regression analyses show that dry matter production (September 8) increased as mulch application rates increased. The greatest yield of grass was produced at 2200 kg/ha for all three mulches (Figure 8). Regression lines, which are plotted in Figure 8 for the September 8 sampling, can be used to predict the dry matter production at a given mulch application rate between the 75 to 95 percent confidence level. R squared (R^2) values obtained from the regression analysis indicate that mulch application rate accounts for approximately 14 to 22 percent of the observed differences in dry matter production.

On the September 30 and October 26 sampling dates dry matter production was not clearly a function of the rates of application of the mulches nor were any of the three types of mulches significantly different from one another. Grass grown at rates greater than 1600 kg/ha tended to have higher dry matter production of red fescue than at rates less than 1600 kg/ha. The changes in dry matter production over time at each rate of application is shown in Figures 9 to 13. Again, the values for Fibramulch have been recalculated using regression equations in order to allow direct comparisons among the data set.

FIGURE #8

LINEAR REGRESSION LINES OF DRY MATTER PRODUCTION VERSUS MULCH APPLICATION RATE (SEPTEMBER 8)

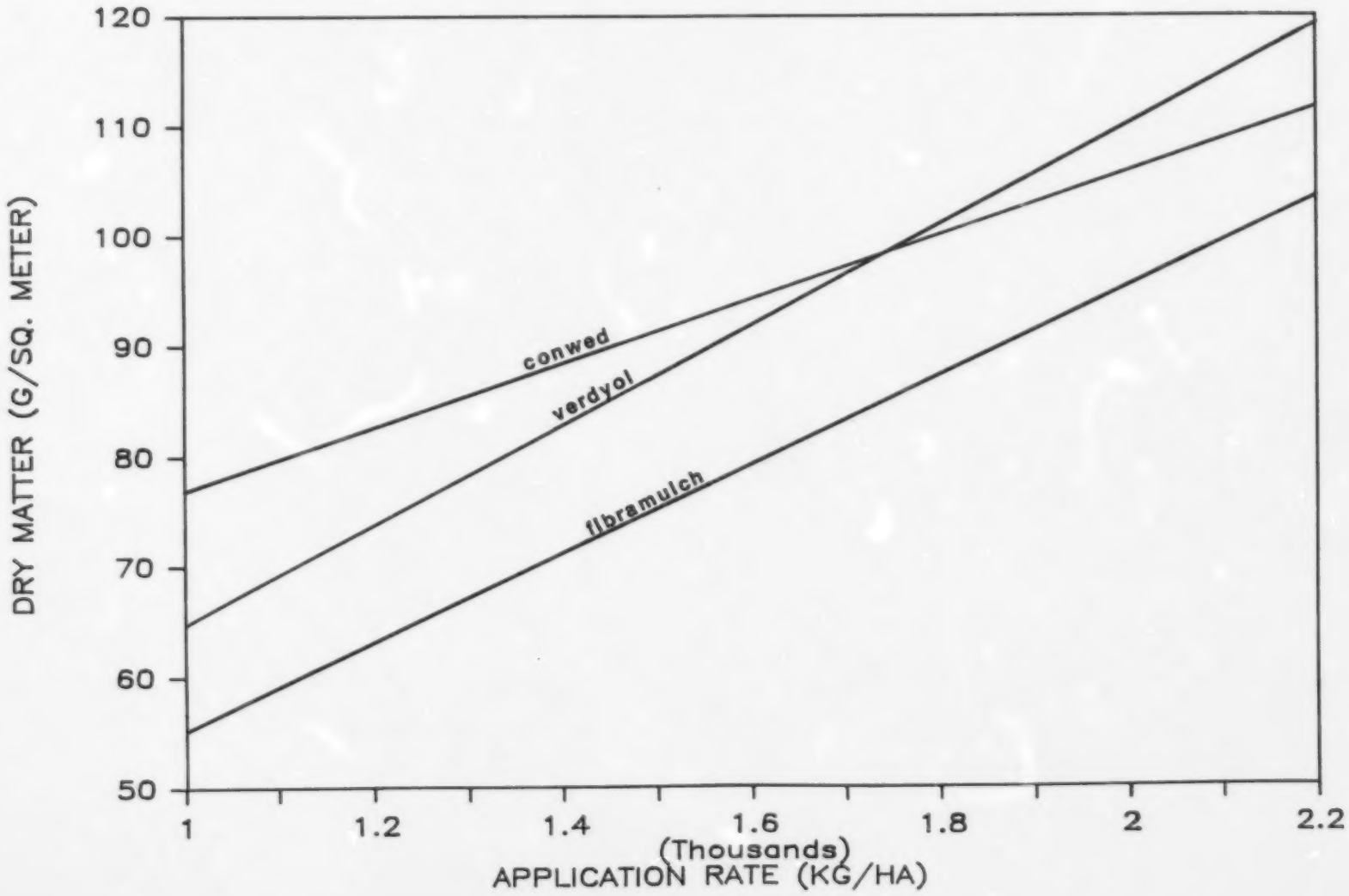


Figure 9: Dry matter production versus time for a 1000 kg/ha mulch application.

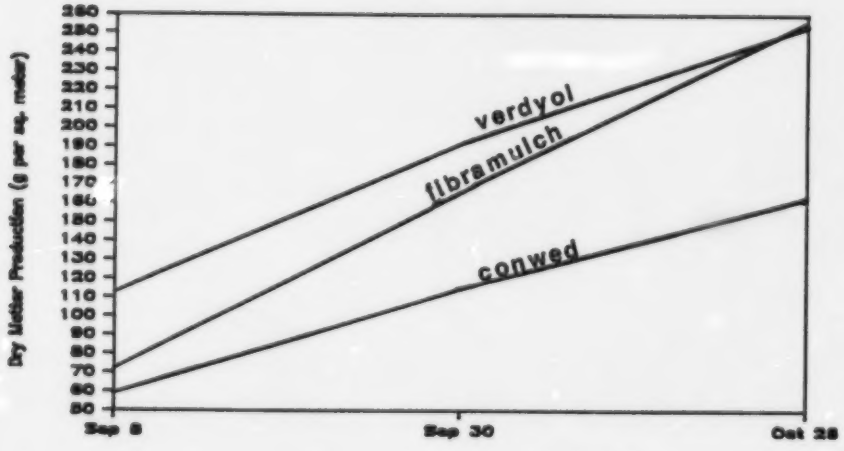


Figure 10: Dry matter production versus time for a 1400 kg/ha mulch application.

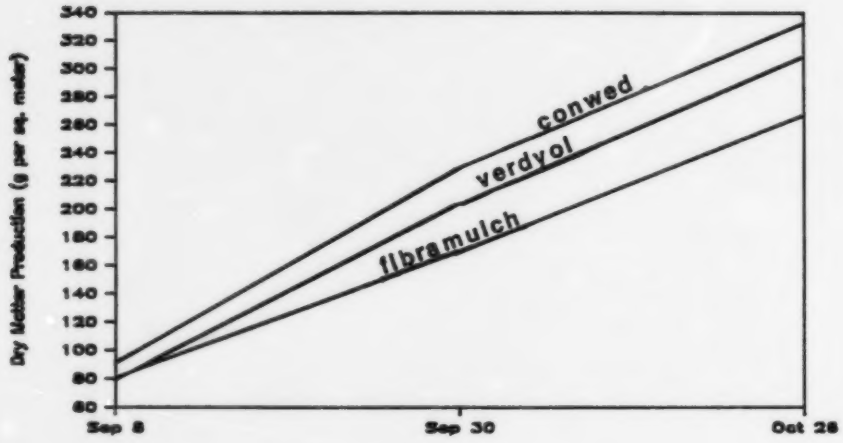


Figure 11: Dry matter production versus time for a 1600 kg/ha mulch application.

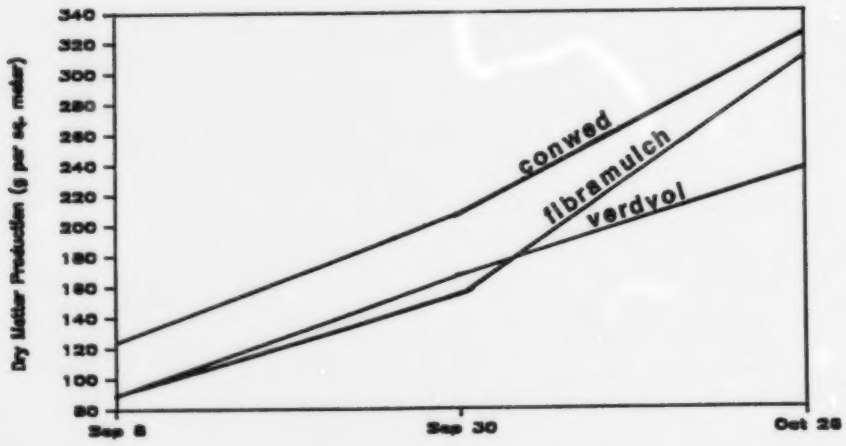


Figure 12: Dry matter production versus time for a 1800 kg/ha mulch application.

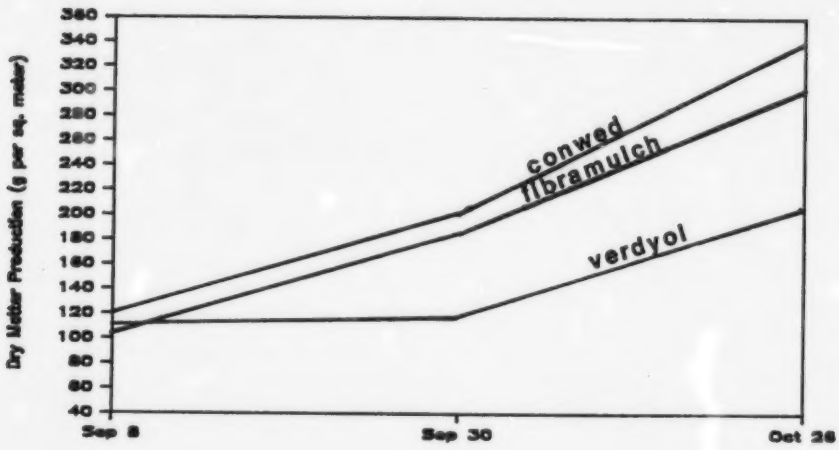


Figure 13: Dry matter production versus time for a 2200 kg/ha mulch application.

D. DISCUSSION OF RESULTS

D.1. Soil Erosion Control

One of the expected benefits of the study, as outlined by the Ministry, was to improve the effectiveness of seeding and mulching operations in supporting turf establishment for slope stabilization. Consequently, several types of observations were made to assess the erosion control of the mulches. A visual assessment of the plots was conducted following a rainfall which occurred within 10 days of the application. The evaluation included a rating of the severity of the erosion and an estimate of the percent ground area occupied by erosion channels. Two more assessments of soil erosion were made, one in July and another in August. Measurements of vegetative coverage served as good indicators of the erosion control provided by the mulches.

Erosion by water is caused by raindrop splash and surface runoff. Rain contains approximately two to three hundred times more kinetic energy than surface runoff whose erosive power is more affected by increased slope and length of slope (Hudson, 1981). Since the angle and length of the slope in this study were the same for all treatments, the ability of the mulch to resist the impact caused by the raindrop to the soil surface determined its ability to resist erosion.

On June 21 and 22, less than one week following the mulch application, a total of 53.7 mm of rain fell, although most of it occurred within two hours. The seed had not germinated and the only protective soil cover was that provided by the mulch.

Straw and Fibramulch provided excellent soil protection following this rainfall event as evidenced by the lack of channel formation and lack of visible erosion.

The thick mat of the straw decreased the energy of the rain that hit the soil surface. Fibramulch, in its formation of a dense mat was also very effective in preventing erosion and tended not to readily break down over the season. Both Conwed and Verdyol were less effective in the prevention of this process, showing some channel formation following the first major rain. Presumably, the tendency for mulches of Conwed and Verdyol to become detached during intense rainfalls, such as those conditions encountered in this study, resulted in reduced erosion control.

Fibramulch at all rates was observed to have been an impedance to germination since the emerging seedlings were often incapable of penetrating the mat formed by this mulch.

On August 11 the layer formed by the Fibramulch at rates of 1237, 1800 and 2165 kg/ha continued to be an impedance to some of the seedlings which were found to be small and curled beneath the dried

mat. The fescue had apparently germinated below the mulch layer since its roots were evident on the soil surface. Thus, turf establishment with Fibramulch may be poor under prolonged dry conditions since the dried Fibramulch has a tendency to become a solid, resistant layer which impedes penetration by grass. It has been shown, however, that the mat formed by the Fibramulch is very resistant to rainfall energy.

In mid-July erosion was evident with Conwed at all rates, Verdyol had fewer channels than Conwed, and very few channels were evident with the Fibramulch. While the straw mulch showed no evidence of soil loss throughout the season, observations revealed that all commercial mulches were eroded to some extent. Channels were less likely to be present at the higher rates of application of all the mulches.

The area occupied by the grass cover was measured since the horizontal vegetative cover could play a major role in the prevention of erosion. Fibramulch resulted in higher vegetative coverage than Conwed and Verdyol, which were similar to one another. While this relationship held for July and August, by September 23, the vigorous growth of the fescue resulted in an average coverage of 82% for all the commercial mulches. It is believed, however, that the establishment of vegetative cover early in the season is of greater importance than that measured later in the season since soil loss

through erosion can occur at any time. A mulch providing substantial vegetative cover by grass shortly after its application would ensure immediate protection of the soil surface.

D.2. Selection of Mulches and Optimal Rates of Application

Measurements of both dry matter production and vegetative cover analysis were used to describe the overall growth and vigour of the red fescue establishment and the extent of lateral spread of the grass. The ability of the grass to branch out gives an indication of its rooting ability which, in turn, is an indication of the contribution it makes to slope stabilization. Horizontal coverage of the grass is considered to be an important factor in erosion control since any soil coverage will reduce the energy of raindrop impact at the soil surface and will therefore reduce soil loss. The vertical growth of the grass can also aid in the reduction of the kinetic energy of rainfall since at some point, high grass may bend over to provide coverage of the soil surface. Both dry matter production and vegetative cover measure the ability of the grass to develop under the conditions provided by the hydroseeding operation and the environment.

All of the grass, including that of the buffer strips, grew more slowly than had been expected considering the good conditions of soil fertility and water status. Apparently, Canada Geese had been thoroughly grazing the field site throughout the early summer. In

late summer and fall the grass grew more rapidly since geese tended to forage elsewhere. It appeared that all plots were uniformly grazed by the geese although it is possible that they preferentially avoided the grass which was covered with a thick layer of straw. It is unknown to what extent the geese affected the dry matter results in this study except that the short height of the grass during summer dictated that no samples could be taken in that period.

At the earliest sampling dates, Conwed, Verdyol, and Fibramulch had the highest dry matter yields and greatest vegetative cover at the mulch application of 2200 kg/ha. The increase in values of dry matter or vegetative cover were linear. As application rates increased between 1000 and 1600 kg/ha values of dry matter and vegetative cover did not consistently increase. This observation is consistent with those of Kay who has studied hydromulching extensively in California. Kay (1978a) summarized findings from various research and stated that a minimum of 1100 kg/ha of mulch was required to secure the seed on a slope, and that below a rate of 1700 kg/ha, no consistent effect of a mulch had been observed.

Since the stated objective of the Ministry was "to determine the application rates for hydraulic mulches specified by the Ministry that will provide equivalent turf establishment, approximating the effectiveness of straw," a comparison of the commercial mulches with the straw mulch follows. Initially, straw was superior in

establishing a good surface coverage and in providing a more prolific growth of grass, as determined by its weight (Table 1). By the conclusion of the sampling program, dry matter production and vegetative cover were approximately equivalent for straw and the three commercial mulches, irrespective of application rates.

Table 2: A comparison of the performance of mulches of Conwed, Verdyol, and Fibramulch relative to straw for the study parameters.

Parameter	Value determined for Straw	Mulch and rate which gave results equal to or better than straw
.Erosion	1.0	all rates of Fibramulch
.Channel Formation	0	all rates of Fibramulch
.Vegetative Cover		
-July 10	88%	none of mulches
-August 10	89%	none of mulches
-Sept. 23	90%	statistically all mulches at all application rates were equivalent to straw
.Dry Matter		
-Sept. 8-11	163 g m^{-2}	none of mulches
-Sept. 30-Oct. 2	149 g m^{-2}	all mulches were equivalent to straw
-Oct. 26-30	240 g m^{-2}	all mulches were equivalent to straw

D.3. Experimental Design and Application Procedures

In this study, a sub-objective was to approximate field application procedures as closely as possible. Unfortunately, the scale of the Ministry field application of mulch is in the order of 1000 to 3000 m^2 per application and with equipment commensurate in size. In this study treatment blocks to which the mulch was applied were 13 m^2, therefore, to apply materials uniformly to the small blocks a comparable scale down of the equipment was necessary. This was not entirely feasible and thus limited the accuracy of the application rate.

On construction sites the Ministry application procedures specify that application rates are controlled by varying the speed of the hydroseeding vehicle as it drives by the site. The site for this study (TCG Materials Ltd. gravel pit) did not have enough space for a drive-by application method. In addition, with the drive-by procedure it would have been virtually impossible to avoid contamination of plots separated by 0.5 m strips of sod.

To accomodate the small, closely spaced plots and the desire to approximate field conditions, a relatively small 1100 L hydroseeder was used for the applications. However, even this small hydroseeder had to be operated at its minimum nozzle pressure. The mulch application rates were controlled by varying the amount of time spent spraying each of the three replications. These problems, related to the method of application, resulted in potential variability in the actual loadings of mulch per plot.

Several different experimental procedures have been used to study mulch/hydroseeding applications (see Bibliography for list of papers by B. Kay). The most common method makes use of flats, 60 x 120 x 15 cm deep, or as small as 28 x 48 cm, inclined at various slopes, and administered with either natural or artificial rainfall, in an outdoor or greenhouse environment. As well, Kay has tested erosion control using a "Spray Baby" hydromulcher on a 4.6 m wide road cut and assessing the degree of erosion visually with a rating of one to ten for the failure or success of the resultant grass stand. Both of these procedures attempt to address the trade-offs associated with meeting the specific requirements for scientific research investigations and the requirements for using standard field application procedures.

In experiments which used the flats, the application of the mulch was by either a (2270 L) Bowie hydroseeder, or by a small (20 L) hydroseeder specially produced for experimental purposes. Measurements were usually made of vegetative cover and soil loss from the system. Soil losses were measured either by measuring the soil in the runoff or by determining the difference in soil weight in the flats before and after the experiment.

Based on experimental designs of other researchers and the experience gained in this study, it is suggested that boxes or flats which could be moved into place following a mulch application by the Ministry

drive-by procedure, should be used. An alternative procedure is to increase the size of the experimental area and scale down the size of the hydroseeder, thereby maintaining the use of the standard Ministry hydroseeding conditions.

The establishment of field plots for experimentation would require a large land area and would be more costly in the application, maintenance and sampling involved. Where catchments for runoff must be set in place in the field for plot work or work with large, immovable flats, more labor and installation is required. Movable flats can be set into place individually during the sampling of runoff from rainfall. In this way, one setup for gathering runoff can be used for each flat successively.

Where boxes or flats are propped up in frames for the duration of the experiment, drying of the soil can occur from above and below the flat and field conditions of soil moisture retention are not provided. Of course, the problem of soil drying can be alleviated by regular watering and the boxes would not need to be maintained at angles between waterings if a rainfall simulator were used for soil loss measurements. It is suggested that the boxes could be stored on the ground after their application and moved onto angled frames for the rainfall application. If natural rainfall conditions were to be used and the boxes were stored in angled frames, more regulation of soil moisture would be required.

E. SUMMARY AND RECOMMENDATIONS

A field study was conducted in order to test the effects of hydroseeding mulches applied at five proposed rates which varied from 1000 to 2200 kg/ha. Three mulches, Conwed, Verdyol, and Fibramulch, were used, and a straw control treatment was included. Measurements included percent vegetative cover and dry matter production.

Red fescue grown under the straw mulch apparently became nitrogen deficient late in the summer, as evidenced by the yellowing of the foliage, and tended not to spread laterally. It is suggested that the erosion control achieved by the application of chopped straw is a function of the straw's preventing the impact of rainfall on the soil surface rather than of the establishment of turf for slope stabilization.

Straw resulted in a uniformly high percentage of vegetative cover early in the season which was not achieved by any of the three commercial mulches. By late September, however, the commercial mulches, at all rates, generally produced an equivalent coverage to the straw with an average for the commercial mulches of 82% vegetative coverage.

In July and August, Fibramulch consistently resulted in better vegetative cover than Conwed or Verdyol. All mulches achieved maximum vegetative cover at the rate of 2200 kg/ha. By September 23 vegetative coverage was similar for all mulches.

The dry matter of grass produced by the beginning of September was greatest under straw while dry matter production was not different among the commercial mulches. Dry matter of the grass grown with commercial mulches caught up with that grown with the straw by the end of September.

Highest dry matter production and vegetative cover percentages were measured where mulches were applied at 2200 kg/ha. Further, a more consistent relationship between the mulch application and the success of grass establishment was observed at rates greater than 1600 kg/ha. Other investigations have also shown that mulch application rates below 1600 kg/ha gave inconsistent results. This would indicate that the 1600 kg/ha application rate, which the Ministry currently uses, is a reasonable minimum mulch application rate. Since the best results were achieved in this study at a mulch application of 2200 kg/ha, the choice of rate should be directed by the costs and benefits of the additional mulch relative to the level of success of the grass cover required for adequate erosion control.

> **Recommendation 1.** It is recommended that commercial mulches are applied at rates greater than 1600 kg/ha.

Assessments of vegetative cover shortly after the hydroseeding operation, and of dry matter production within the first three months following the application, indicate that straw is superior to the commercial mulches.

Since turf establishment and slope stabilization are the main objectives of hydroseeding, the evaluation of the various mulches and application rates should reflect the erosion control potential of the mulches in the early stages of revegetation. In this study, the horizontal coverage by the grass was measured by percent vegetative cover; this measurement was considered more relevant than dry matter production. Dry matter production is a measure of the entire plant biomass produced without consideration of its areal distribution at the soil surface. Horizontal vegetative coverage, on the other hand, was considered a good measure of the potential erosion control of the various treatments.

The assessments made in this study provide a basis for a more erosion-specific examination of the effects of various factors involved in hydroseeding, such as mulch materials and their application rates. As a result of the difficulties encountered in the present study, concerning the incompatible plot size and scale of machinery, which limited the accuracy in the application rates, it is suggested that the present experimental design should be improved. This should include either fully scaling up the entire operation, or properly scaling down the operation to include the use of movable flats.

Recommendation 2: It is recommended that a standardized experimental procedure is developed for evaluating the erosion control potential of different mulch application rates.

Recommendation 3: It is recommended that some measure of vegetative ground cover is used in comparisons of the erosion control potential of various mulches.

It is suggested that an experimental design which includes scaling down the operation could most effectively provide a procedure that could be used in the evaluation of new mulches as they become available. The procedure for testing the hydraulic mulches should likely include the use of flats which could be set into place for the hydromulching operation using the drive-by procedure. Other changes to consider in the experimental design include the use of more controlled experimental conditions by use of rainfall simulators. The erosion control potential could be correlated with measurements of vegetative cover and sediment or soil loss from the hydromulched system.

An initial test of reasonable rates of application of the mulches may be conducted by evaluating the germination success of grass or grass mixes beneath various rates of mulch above 1600 kg/ha. The intention of such a test would be to provide a range of rates of mulch within which the growth of the grass is not severely impeded. The range of rates of mulch may then be tested for their ability to control erosion. The success of a particular mulch may be improved at a given rate with the use of tackifiers to ensure its stability on a slope.

Recommendation 4: It is recommended that further research is conducted which evaluates the effects of tackifiers, used in conjunction with mulches, on erosion control.

Measurements of sediment loss or rill formation, or some areal measure, such as vegetative cover, could be used to assess the mulch plus tackifier. The results would ultimately be compared with those from the straw mulch since the objectives of the research are to provide equivalence to straw, which has been demonstrated as a superior mulch.

F. BIBLIOGRAPHY

Hudson, N. 1981. Soil Conservation. Second edition. Cornell University Press, Ithaca, New York.

Kay, Burgess L. 1972. New mulch materials tested for hydroseeding. Agronomy Progress Report No. 39. University of California, Davis.

Kay, Burgess L. 1973. Erosion-control products tested in the Tahoe area. Agronomy Progress Report No. 48. University of California, Davis.

Kay, Burgess L. 1973. Screening of erosion-control products. Agronomy Progress Report No. 49. University of California, Davis.

Kay, Burgess L. 1973. Wood fiber mulch studies. Agronomy Progress Report No. 52. University of California, Davis.

Kay, Burgess L. and Mearns, R. 1973. Erosion-control treatments on fine sand. Agronomy Progress Report No. 58. University of California, Davis.

Kay, Burgess L. 1973. Hydroseeding. Agrichemical Age, June 1973.

Kay, Burgess L. 1974. Erosion control treatments on coarse decomposed granite. Agronomy Progress Report No. 60. University of California, Davis.

Kay, Burgess L. 1978. Mulches for erosion control and plant establishments on disturbed sites. Agronomy Progress Report No. 87. University of California, Davis.

Kay, Burgess, L. 1978a. Mulch and chemical stabilizers for land reclamation in dry regions. Ch. 26 In: Reclamation of drastically disturbed lands. ASA-CSSA-SSSA, Madison, Wisc.

Kay, Burgess, L. 1979. Hydromulching fibers- what's new? Agronomy Progress Report No. 98. University of California, Davis.

Kay, Burgess L. 1979. Hydraulic seeding is not the only way. Proceedings of Conference X International Erosion Control Association, March 1 & 2, 1979.

Kay, Burgess L. 1980. Effect of hydraulic mulch rates on erosion control. Proceedings of Conference XI, International Erosion Control Association, February 29, 1980.

Kay, Burgess L. 1983. Straw as an erosion control mulch. Agronomy Progress Report No. 140. University of California, Davis.

Kay, Burgess L. 1987. Modifications of seedbeds with natural and artificial mulches. Proceedings Symposium: Seed and Seedbed Ecology of Rangeland Plants. USDA, Tucson, Az., April, 1987.

Appendix A

Data, Means, and ANOVA for Study Parameters

Percent Vegetative Cover, July 10

Trt.	Material (A)	Rate (B)	REP I	REP II	REP III	MEAN
1	Conwed	1000	49.70	63.30	26.10	46.367
2		1400	60.70	27.20	22.00	36.633
3		1600	47.90	64.60	46.00	52.833
4		1800	46.40	59.40	47.80	51.200
5		2200	83.30	54.40	62.60	66.767
6	Verdyol	1000	44.00	29.70	31.90	35.200
7		1400	36.50	52.10	36.20	41.600
8		1600	65.20	55.50	38.40	53.033
9		1800	54.40	58.00	44.30	52.233
10		2200	59.30	86.40	65.10	70.267
11	Fibramulch	1237	68.00	38.10	46.30	50.800
12		1735	65.90	48.40	43.10	52.467
13		1800	74.30	86.20	82.50	81.000
14		1940	57.80	52.80	61.40	57.333
15		2165	77.80	68.40	49.40	65.200
16	Straw		80.60	89.80	92.10	87.500
REP AVE			60.74	58.39	49.70	

TREATMENT MEANS:

TR. NO.		B1	2	3	4	5	MEAN
1 - 5	A 1	46.367	36.633	52.833	51.200	66.767	50.760
6 -10	A 2	35.200	41.600	53.033	52.233	70.267	50.467
11 -15	A 3	50.800	52.467	81.000	57.333	65.200	61.360
	MEAN	44.122	43.567	62.289	53.589	67.411	54.196

CHECK MEAN(S) 87.50000

Source	D.F.	SS	MS	F	Probability
Total	47	14548.6			
Blocks	2	1082.1	541.06	4.282	.01<p<.025
Treatments	15	9676.0	645.06	5.106	p<.005
Material	2	1155.5	577.77	4.573	.01<p<.025
Checks vs Rest	1	3119.5	3119.58	24.691	p<.005
Error	30	3790.4	126.34		

Standard Error 6.489
Coefficient of Variability 19.97

Vegetative Cover, July 10

Ranked Treatment	Mean	Duncan's Multiple Range Test
Straw	87.5	
Fibramulch @1940	81	
Verdyol @2200	70.2	
Conwed @2200	66.7	
Fibramulch @2165	65.2	
Fibramulch @1800	57.3	
Verdyol @1600	53	
Conwed @1600	52.8	
Fibramulch @1735	52.4	
Verdyol @1800	52.2	
Conwed @1800	51.2	
Fibramulch @1237	50.8	
Conwed @1000	46.3	
Verdyol @1400	41.6	
Conwed @1400	36.6	
Verdyol @1000	35.2	

Percent Vegetative Cover, August 10

Trt.	Material (A)	Rate (B)	REP I	REP II	REP III	MEAN
1	Conwed	1000	54.00	71.30	33.80	53.033
2		1400	56.60	29.20	33.20	39.667
3		1600	56.20	64.20	38.60	53.000
4		1800	38.50	73.80	66.40	59.567
5		2200	83.20	53.30	72.20	69.567
6	Verdyol	1000	46.00	35.10	27.20	36.100
7		1400	52.20	60.10	38.90	50.400
8		1600	58.20	69.10	42.70	56.667
9		1800	58.60	55.30	52.70	55.533
10		2200	62.00	76.80	58.00	65.600
11	Fibramulch	1237	78.30	57.20	49.00	61.500
12		1735	68.50	70.60	44.80	61.300
13		1800	88.00	80.80	80.70	83.167
14		1940	65.40	66.80	70.20	67.467
15		2165	92.10	81.20	53.90	75.733
16	Straw		85.00	86.10	95.80	88.967
REP AVE			65.18	64.43	53.63	

TREATMENT MEANS:

TR. NO.		B1	2	3	4	5	MEAN
1 - 5	A 1	53.033	39.667	53.000	59.567	69.567	54.967
6 -10	A 2	36.100	50.400	56.667	55.533	65.600	52.860
11 -15	A 3	61.500	61.300	83.167	67.467	75.733	69.833
	MEAN	50.211	50.456	64.278	60.856	70.300	59.220

CHECK MEAN(S) 88.96667

Source	D.F.	SS	MS	F	Probability
Total	47	14348.0			
Blocks	2	1335.7	667.8	4.967	.01<p<.025
Treatments	15	8978.5	598.5	4.452	p<.005
Material	2	2567.7	1283.8	9.548	p<.005
Checks vs Rest	1	2488.6	2488.6	18.509	p<.005
Error	30	4033.7	134.4		

Standard Error 6.694
Coefficient of Variability 18.98

Vegetative Cover, August 10

Ranked Treatment	Mean	Duncan's Multiple Range Test
Straw	88.9	
Fibramulch @1940	83.2	
Fibramulch @2165	75.7	
Conwed @2200	69.5	
Fibramulch @1800	67.4	
Verdyol @2200	65.6	
Fibramulch @1237	61.5	
Fibramulch @1735	61.3	
Conwed @1800	59.5	
Verdyol @1600	56.6	
Verdyol @1800	55.5	
Conwed @1000	53	
Conwed @1600	53	
Verdyol @1400	50.4	
Conwed @1400	39.6	
Verdyol @1000	36.1	

Percent Vegetative Cover, September 23

Trt.	Material (A)	Rate (B)	REP I	REP II	REP III	MEAN
1	Conwed	1000	80.70	93.00	72.30	82.000
2		1400	83.80	60.10	56.30	66.733
3		1600	76.50	94.10	84.00	84.867
4		1800	77.60	84.50	79.90	80.667
5		2200	88.50	64.60	79.60	77.567
6	Verdyol	1000	73.00	62.10	77.20	70.767
7		1400	86.50	80.50	86.40	84.467
8		1600	85.80	77.40	75.10	79.433
9		1800	83.30	83.60	74.00	80.300
10		2200	85.00	95.60	83.90	88.167
11	Fibramulch	1237	95.20	78.50	82.90	85.533
12		1735	83.30	75.80	75.40	78.167
13		1800	96.50	93.20	88.30	92.667
14		1940	79.20	81.00	86.10	82.100
15		2165	92.00	94.50	84.20	90.233
16	Straw		88.40	82.40	98.50	89.767
REP AVE			84.71	81.31	80.26	

TREATMENT MEANS:

TR. NO.		B1	2	3	4	5	MEAN
1 - 5	A 1	82.000	66.733	84.867	80.667	77.567	78.367
6 -10	A 2	70.767	84.467	79.433	80.300	88.167	80.627
11 -15	A 3	85.533	78.167	92.667	82.100	90.233	85.740
	MEAN	79.433	76.456	85.656	81.022	85.322	81.578

CHECK MEAN(S) 89.76667

Source	D.F.	SS	MS	F	Probability
Total	47	4058.60			
Blocks	2	173.14	86.57	1.483	.10<p<.25
Treatments	15	2134.33	142.28	2.438	.010<p<.025
Material	2	428.09	214.04	3.667	.025<p<.05
Checks vs Rest	1	188.60	188.60	3.231	.05<p<.10
Error	30	1751.12	58.37		

Standard Error 4.411
Coefficient of Variability 9.30

Vegetative Cover, September 23

Ranked Treatment	Mean	Duncan's Multiple Range Test
Fibramulch @1940	92.6	
Fibramulch @2165	90.2	
Straw	89.7	
Verdyol @2200	88.2	
Fibramulch @1237	85.5	
Conwed @1600	84.8	
Verdyol @1400	84.4	
Fibramulch @1800	82.1	
Conwed @1000	82.0	
Conwed @1800	80.6	
Verdyol @1800	80.3	
Verdyol @1600	79.4	
Fibramulch @1735	78.2	
Conwed @2200	77.5	
Verdyol @1000	70.7	
Conwed @1400	66.7	

Dry Matter Production (g m^{-2}), September 8 - 11

Trt.	Material (A)	Rate (B)	REP I	REP II	REP III	MEAN
1	Conwed	1000	78.23	60.56	103.83	80.871
2		1400	92.37	59.67	21.81	57.951
3		1600	78.25	44.23	113.11	78.529
4		1800	95.72	89.59	183.84	123.049
5		2200	87.31	126.73	145.45	119.831
6	Verdyol	1000	110.44	63.20	22.41	65.351
7		1400	99.79	133.59	106.49	113.289
8		1600	84.92	110.15	78.84	91.302
9		1800	56.73	100.91	111.88	89.840
10		2200	112.60	101.67	121.57	111.947
11	Fibramulch	1237	58.95	82.61	81.24	74.267
12		1735	53.97	32.80	101.52	62.764
13		1800	95.56	68.49	122.03	95.360
14		1940	43.19	93.87	127.87	88.307
15		2165	95.57	75.92	164.76	112.084
16	Straw		117.92	170.80	200.37	163.031
REP AVE			85.10	88.42	112.94	

TREATMENT MEANS:

TR. NO.		B1	2	3	4	5	MEAN
1 - 5	A 1	80.871	57.951	78.529	123.049	119.831	92.046
6 -10	A 2	65.351	113.289	91.302	89.840	111.947	94.346
11 -15	A 3	74.267	62.764	95.360	88.307	112.084	86.556
	MEAN	73.496	78.001	88.397	100.399	114.621	90.983

CHECK MEAN(S) 163.03111

Source	D.F.	SS	MS	F	Probability
Total	47	69507.0			
Blocks	2	7399.4	3699.7	3.901	.025<p<.05
Treatments	15	33654.4	2243.6	2.366	.010<p<.025
Material	2	480.4	240.2	0.253	p>.25
Checks vs Rest	1	14599.5	14599.5	15.393	p<.005
Error	30	28453.0	948.4		

Standard Error 17.780
Coefficient of Variability 32.25

Dry Matter Production, September 8

Ranked Treatment	Mean	Duncan's Multiple Range Test
Straw	163.0	a
Conwed @1800	123.0	b
Conwed @2200	119.8	b
Verdyol @1400	113.2	b c
Fibramulch @2165	112.0	b c
Verdyol @2200	111.9	b c
Fibramulch @1940	95.3	c d
Verdyol @1600	91.3	c d
Verdyol @1800	89.8	c d
Fibramulch @1800	88.3	c d
Conwed @1000	80.8	c d
Conwed @1600	78.5	c d
Fibramulch @1237	74.2	c d
Verdyol @1000	65.3	d
Fibramulch @1735	62.7	d
Conwed @1400	57.9	d

Dry Matter Production (g m^{-2}), September 30 - October 2

Trt.	Material (A)	Rate (B)	REP I	REP II	REP III	MEAN
1	Conwed	1000	103.20	234.27	153.73	163.733
2		1400	96.53	135.60	109.87	114.000
3		1600	211.60	179.33	220.40	203.778
4		1800	189.47	235.60	196.93	207.333
5		2200	186.27	206.80	213.33	202.133
6	Verdyol	1000	159.20	167.60	152.67	159.822
7		1400	152.67	223.07	200.00	191.911
8		1600	199.33	203.33	287.33	230.000
9		1800	119.60	137.07	246.93	167.867
10		2200	83.47	133.60	141.07	119.378
11	Fibramulch	1237	239.87	147.73	188.27	191.956
12		1735	83.33	149.20	155.33	129.289
13		1800	100.67	184.67	224.53	169.956
14		1940	100.93	85.60	277.20	154.578
15		2165	212.53	219.20	250.67	227.467
16	Straw		130.53	112.93	202.40	148.622
REP AVE			148.08	172.23	201.29	

TREATMENT MEANS:

TR. NO.		B1	2	3	4	5	MEAN
1 - 5	A 1	163.733	114.000	203.778	207.333	202.133	178.196
6 -10	A 2	159.822	191.911	230.000	167.867	119.378	173.796
11 -15	A 3	191.956	129.289	169.956	154.578	227.467	174.649
	MEAN	171.837	145.067	201.244	176.593	182.993	175.547

CHECK MEAN(S) 148.62222

Source	D.F.	SS	MS	F	Probability
Total	47	132822			
Blocks	2	22720	11360	6.563	$p<.005$
Treatments	15	58173	3878	2.241	$.025<p<.05$
Material	2	163	81	0.047	$p>.25$
Checks vs Rest	1	2038	2038	1.178	$p>.25$
Error	30	51928	1730		

Standard Error 24.020
Coefficient of Variability 23.92

Dry Matter Production, September 30

Ranked Treatment	Mean	Duncan's Multiple Range Test
Verdyol @1600	230.0	
Fibramulch @2165	227.4	
Conwed @1800	207.3	
Conwed @1600	203.7	
Conwed @2200	202.1	
Fibramulch @1237	191.9	
Verdyol @1400	191.9	
Fibramulch @1940	169.9	
Verdyol @1800	167.8	
Conwed @1000	163.7	
Verdyol @1000	159.8	
Fibramulch @1800	154.5	
Straw	148.6	
Fibramulch @1735	129.2	
Verdyol @2200	119.3	
Conwed @1400	114.0	

Dry Matter Production (g m^{-2}), October 26 - 30

Trt.	Material (A)	Rate (B)	REP I	REP II	REP III	MEAN
1	Conwed	1000	174.67	180.13	223.47	192.756
2		1400	156.40	191.20	138.67	162.089
3		1600	254.93	328.27	344.00	309.067
4		1800	205.73	405.73	366.93	326.133
5		2200	174.00	371.07	479.07	341.378
6	Verdyol	1000	189.73	187.87	247.73	208.444
7		1400	271.20	281.47	209.47	254.044
8		1600	305.07	448.67	245.73	333.156
9		1800	119.60	224.80	369.33	237.911
10		2200	72.27	263.87	287.60	207.911
11	Fibramulch	1237	273.73	196.80	290.00	253.511
12		1735	136.93	264.80	315.20	238.978
13		1800	177.47	280.80	377.60	278.622
14		1940	242.93	361.60	326.40	310.311
15		2165	272.13	315.47	339.87	309.156
16	Straw		189.47	176.67	352.40	239.511
REP AVE			201.02	279.95	307.09	

TREATMENT MEANS:

TR. NO.		B1	2	3	4	5	MEAN
1 - 5	A 1	192.756	162.089	309.067	326.133	341.378	266.284
6 -10	A 2	208.444	254.044	333.156	237.911	207.911	248.293
11 -15	A 3	253.511	238.978	278.622	310.311	309.156	278.116
	MEAN	218.237	218.370	306.948	291.452	286.148	264.231

CHECK MEAN(S) 239.51111

Source	D.F.	SS	MS	F	Probability
Total	47	369559			
Blocks	2	97168	48584	10.572	p<.005
Treatments	15	134522	8968	1.951	.05<p<.10
Material	2	6765	3382	0.736	p>.25
Checks vs Rest	1	1718	1718	0.374	p>.25
Error	30	137868	4595		

Standard Error 39.139
Coefficient of Variability 25.80

Dry Matter Production, October 26

Ranked Treatment	Mean	Duncan's Multiple Range Test
Conwed @2200	341.3	
Verdyol @1600	333.2	
Conwed @1800	326.1	
Fibramulch @1800	310.3	
Fibramulch @2165	309.2	
Conwed @1600	309.1	
Fibramulch @1940	278.6	
Verdyol @1400	254.0	
Fibramulch @1237	253.5	
Straw	239.5	
Fibramulch @1735	238.9	
Verdyol @1800	237.9	
Verdyol @1000	208.4	
Verdyol @2200	207.9	
Conwed @1000	192.7	
Conwed @1400	162.1	

Appendix B

Regression Parameters

Linear regression parameters calculated for percent vegetative cover

Date	Mulch	F	R^2	Intercept	b	Probability of Significance
July 10	Conwed	3.83	22.7	21	.018941	.05<p<.10
	Verdyol	20.3	60.9	4	.028958	p<.005
	Fibramulch	3.95	23.3	21	.022663	.05<p<.10
August 10	Conwed	2.82	17.8	27	.017375	p>.25
	Verdyol	15.9	55.1	15	.023408	p<.005
	Fibramulch	3.20	19.7	34	.019674	.05<p<.10
Sept. 23	Conwed	.00	0.0	78	.0001583	p>.25
	Verdyol	8.71	40.1	61	.0120083	.010<p<.025
	Fibramulch	1.30	9.1	73	.0068332	p>.25

Linear regression parameters calculated for dry matter production

Date	Mulch	F	R^2	Intercept	b	Probability of Significance
Sept. 8 -11	Conwed	3.63	21.8	19	.045494	.05<p<.10
	Verdyol	2.76	17.5	47	.029084	.10<p<.25
	Fibramulch	2.09	13.8	14	.040373	.10<p<.25
Sept. 30 - Oct. 2	Conwed	3.42	20.8	94	.052133	.05<p<.10
	Verdyol	1.15	8.1	231	-.03634	p>.25
	Fibramulch	0.21	1.6	130	.025108	p>.25
Oct. 26 - 30	Conwed	6.98	34.9	22	.152477	.010<p<.025
	Verdyol	0.01	0.04	255	-.004433	p>.25
	Fibramulch	1.08	7.6	173	.059020	p>.25

Second order regression parameters calculated for percent vegetative cover

Date	Mulch	F	R^2	Intercept	b_o	b_1	Rate Max.	Rate Min.	Probability of Significance	Rate of Maximum Vegetative coverage
July 10	Conwed	2.64	30.5	85	-.06756	.00002703	--	1219	.10<p<.25	2200
	Verdyol	9.87	62.2	28	-.003136	.00001002	--	157	p<.005	2200
	Fibramulch	1.83	23.3	29	.01274	.00000295	--	--	.10<p<.25	2200
August 10	Conwed	2.24	27.2	100	-.08100	.00003074	--	1319	.10<p<.25	2200
	Verdyol	7.97	57.0	-10	.05766	-.00001070	2695	--	.005<p<.01	2200
	Fibramulch	1.57	20.7	73	-.02821	-.00000976	--	993	.10<p<.25	2200
Sept. 23	Conwed	.03	0.55	90	-.01523	.00000481	--	1587	p>.25	2200
	Verdyol	4.23	41.4	49	.02854	-.00000516	2799	--	.025<p<.05	2200
	Fibramulch	2.31	27.8	159	-.09895	.00000814	--	1570	.10<p<.25	2200

Second order regression parameters calculated for dry matter production

Date	Mulch	F	R^2	Intercept	b_o	b_1	Rates Max.	Rates Min.	Probability of Significance	Rate of Maximum Dry Matter
Sept. 8 -11	Conwed	2.02	25.2	124	-.09392	.00004357	--	1080	.10<p<.25	2200
	Verdyol	1.49	19.9	-15	.1129	-.00002622	2156	--	p>.25	2156
	Fibramulch	1.60	21.1	269	-.2744	.00009386	--	1463	.10<p<.25	2200
Sept. 30 - Oct. 2	Conwed	1.61	21.1	130	.004302	.00001494	--	--	.10<p<.25	2200
	Verdyol	4.22	41.3	-199	.5382	-.0001795	1499	--	.025<p<.05	1499
	Fibramulch	2.44	28.9	1036	-1.0972	.0003345	--	1640	.10<p<.25	1000
Oct. 26 - 30	Conwed	3.23	35.0	0.70	.1813	-.0000090	10072	--	.05<p<.10	2200
	Verdyol	1.14	16.0	-263	.6876	-.0002162	1590	--	p>.25	1590
	Fibramulch	0.57	8.6	353	.1640	.00006648	--	1235	p>.25	2200

Appendix C

Rainfall Records

Precipitation Data from the Guelph Arboretum Station
June 15 - October 31, 1987